Extreme thermophilic biohydrogen production from arabinose and glucose

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HIGHLIGHTS

Continuous hydrogen production rate from arabinose was significantly higher than from glucose, when higher organic loading rate was used. This fact was associated to higher lactate production in the reactor fed with glucose. The higher concentration of lactate was not a consequence of bacterial community shift, and is likely related to changes in the main metabolic pathways of glucose catabolism.

Keywords
Biohydrogen; extreme thermophilic conditions; lactate; hydrogen partial pressure

INTRODUCTION

Second generation hydrogen fermentation technologies using organic agricultural and forestry wastes are emerging. The efficient microbial fermentation of hexoses and pentoses resulting from the pretreatment of lingocellulosic materials is essential for the success of these processes.
Fermentation processes operating under extreme thermophilic temperatures (65-80ºC) could possibly result in higher hydrogen yields due to favourable thermodynamics and lower variety in soluble by-products. High temperatures inhibit the growth of methanogenic archaea and homoacetogenic bacteria (van Groenestijn *et al*. 2002). Also, higher hydrolysis rates of cellulosic material have been observed in studies performed under thermophilic conditions, with the concurrent formation of higher amounts of fermentable sugars (Lu *et al.* 2008).
In the present study, the conversion of arabinose and glucose to hydrogen, using anaerobic mixed-cultures under extreme thermophilic conditions (70ºC) was studied in continuous expanded granular sludge bed (EGSB) reactors.

MATERIAL AND METHODS

Two EGSB reactors, R_{arab} and R_{gluc} were continuously fed with arabinose and glucose, respectively. Arabinose and glucose concentration differed in order to have identical theoretical hydrogen yields in both reactors (i.e. 33.3, 55.5 and 110.8 mM H_2 for periods I, II and III, respectively). Microbial diversity in arabinose- and glucose-fed bioreactors was assessed using a PCR-DGGE approach.

RESULTS AND DISCUSSION

No significant differences in reactor performance were observed for arabinose and glucose organic loading rates (OLR) ranging from 4.3 to 7.1 kgCOD m^{-3} d^{-1}. However, for an OLR of 14.2 kgCOD m^{-3} d^{-1}, hydrogen production rate and hydrogen yield were higher in R_{arab} than in R_{gluc} (average hydrogen production rate of 3.2 and 2.0 LH_2 L^{-1} d^{-1} and hydrogen yield of 1.10 and 0.75 $molH_2$ mol^{-1}substrate for R_{arab} and R_{gluc}, respectively). Lower hydrogen production in R_{gluc} was associated with higher lactate production.
According to the Embden-Meyerhof pathway, sugar-derived pyruvate is reduced to lactate, with regeneration of NADH or oxidized to acetyl-CoA, with the production of reduced ferredoxin. The first reaction does not yield hydrogen, while in the second reaction one mol of pyruvate results in

the formation of 2 mol hydrogen. However, and considering Gibbs energy variations, the reaction that results regeneration of NADH seems to be energetically more favourable (-25 KJ reaction^{-1}) than the reaction yielding acetyl-CoA (+3 KJ reaction^{-1}), especially at higher hydrogen partial pressures.

DGGE results revealed no significant difference on the bacterial community composition between operational periods and between the reactors. This fact suggests that the higher concentration of lactate produced in R_{gluc} with higher organic loading rate is related to metabolic changes and is not a consequence of bacterial community shifts.

Table 1. Process performance of arabinose reactor and glucose reactor.

	Feed concentration (mM)	Hydrogen yield (molH$_2$ mol substrate consumed^{-1})	Hydrogen production rate (LH$_2$ L^{-1} d^{-1})
Glucose reactor	8.3	0.34±0.05	0.32±0.02
	13.8	0.80±0.03	1.15±0.04
	27.7	0.75±0.07	2.10±0.06
Arabinose reactor	10.0	0.23±0.01	0.24±0.01
	16.6	0.77±0.02	1.36±0.04
	33.3	1.10±0.01	3.26±0.16

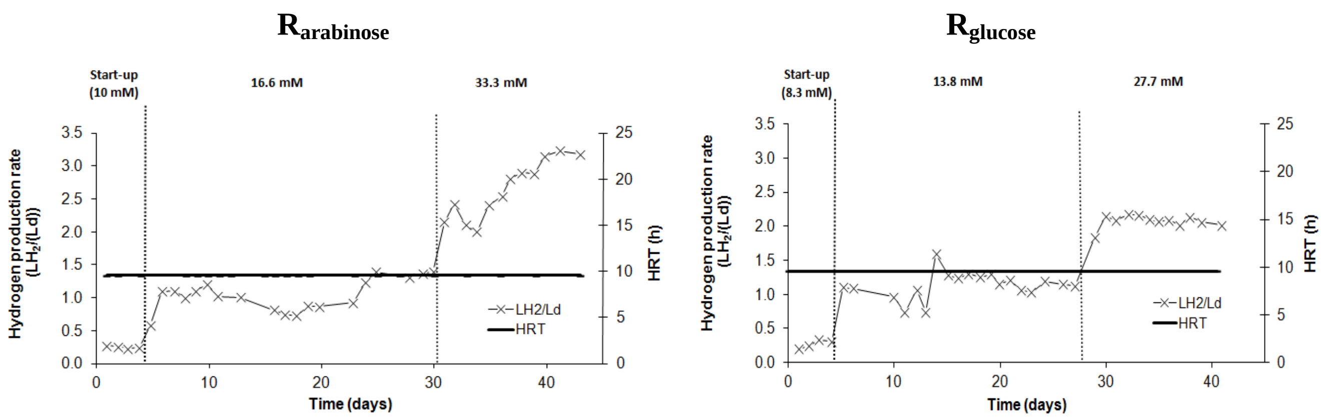

Figure 1. Effect of OLR on performance of arabinose and glucose reactors.

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